GROUP II REPORT

DARPA Camera Ab Initio Workshop
April 29, 2003
Arlington, VA

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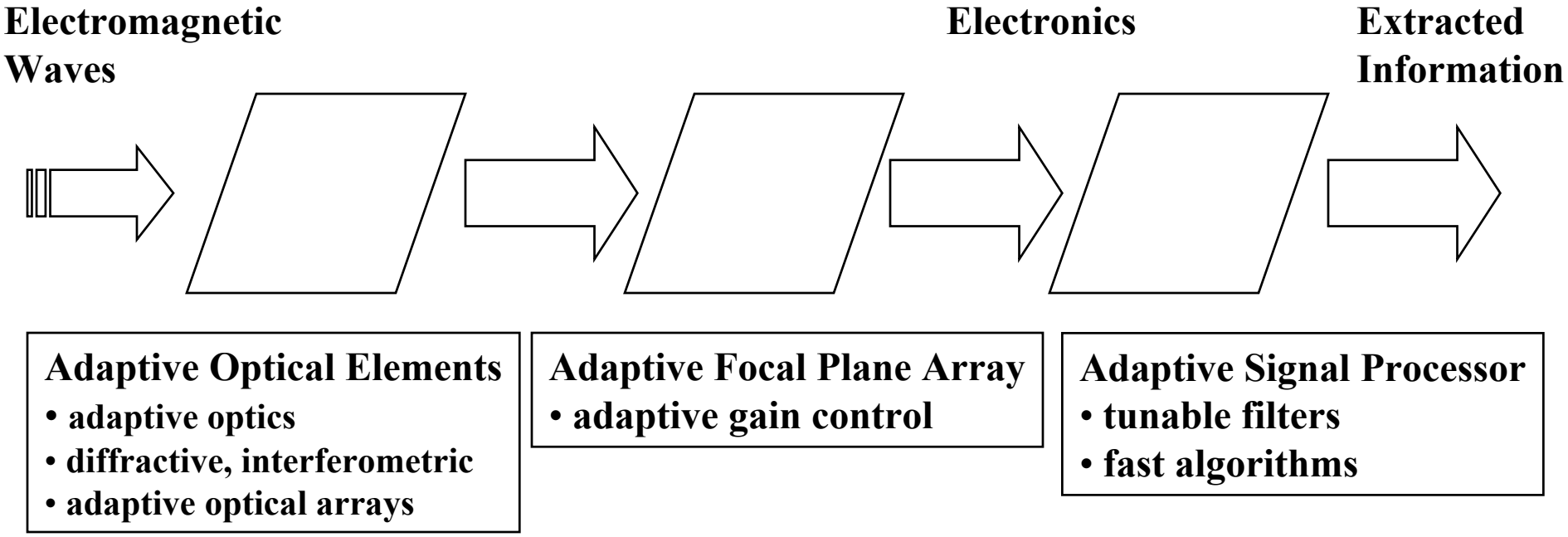
Adaptive Imaging Sensors:

digitally controlled adaptive optics, adaptive sampling, information extraction



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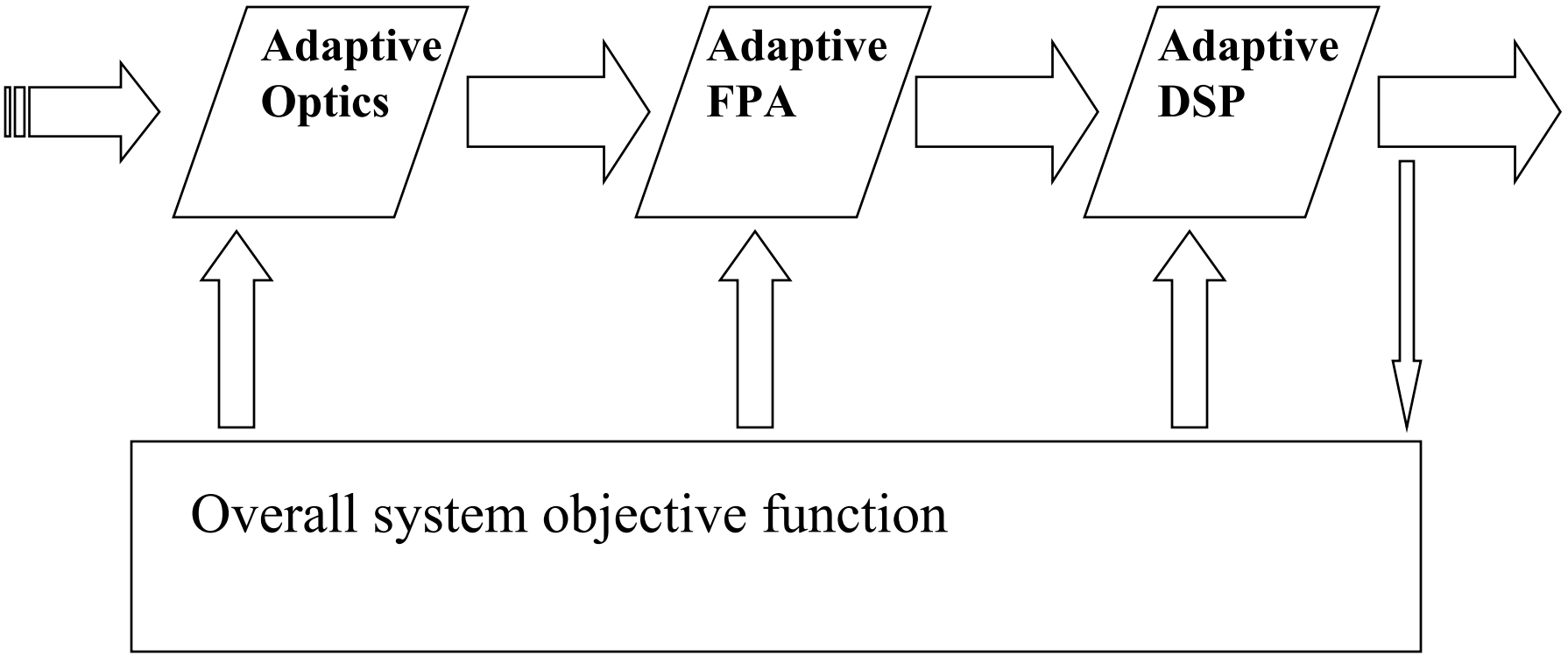
Adaptive Imaging Sensors:
Systems View



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System Concepts

- Information Extraction
- Adaptive Optical Arrays
  - Radar Analog to Optics
  - Time Delay vs. Optical Preprocesing
- Diffractive/Interferometric Coded Optics
  - Coded Apertures for Tomographic or Phase Coherent Processing
- Adaptive Optics
  - Sparse Apertures
  - Horizonal Path Imaging
  - Foveated Imaging System

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Enabling Technologies (new or evolving)

- Wave Front Sensing Focal Plane Arrays (2K x 2K @10K fps and 1e Read Noise
- Spatial Light Modulators (a) MEMS 1K x 1K w/ several microns of dynamic range; (b) LQ need increased speed and 10's of microns shifting plus solve other problems
- Algorithms That Leverage Other New Optical Capabilities (a) e.g., 3-D Optical Tomography; (b) all other heuristic possibilities
- Massively Parallel Analog/Digital Processors: miniturized, low-power, compact
- Photonic Bandgap Materials or Other Tunable Wavelength Materials: Guided Wave Structures or Programable Index of Refraction

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New Capabilities

- AOA
  - Large, Flat Array Passive Imaging
  - Synthetic Aperture Systems
  - Feature Selection
- DICO
  - Digitally Controlled Diffraction to Collect Selected Spatial or Spectral Features
- AO
  - Foveated Imaging Systems
  - Sparse Aperture Systems for High Resolution yet Compact Imagers
  - Imaging Over Horizontal Path

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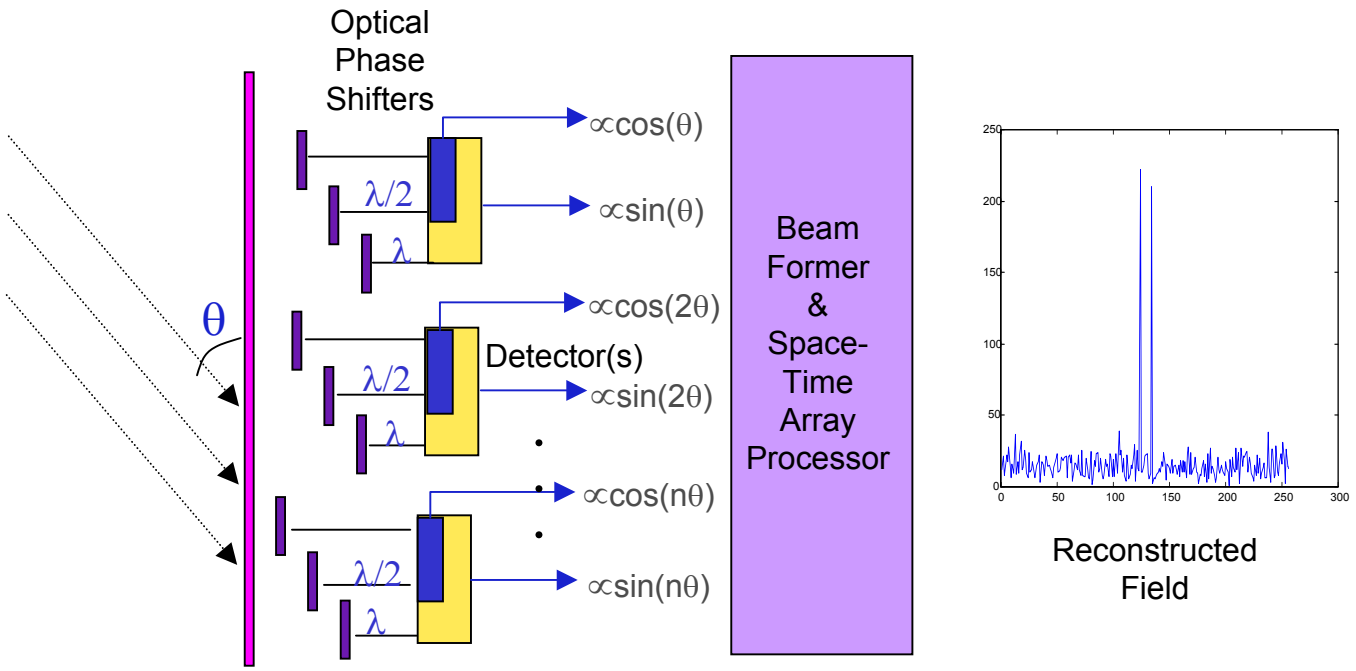
AOA System Concept



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Imaging with Sparse-Aperture Telescopes

- Sparse-aperture telescopes and multiple-telescope interferometers make possible fine-resolution imaging with light-weight, deployable optics
- Phase retrieval or phase diversity sensors keep them aligned
- Image restoration algorithms produce high-quality images from blurred raw images
- Scaling laws, image quality equations help engineers design useful systems

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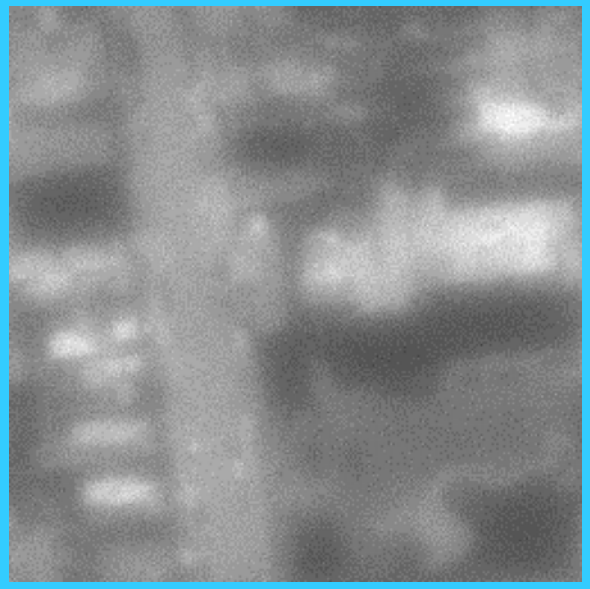
RAW IMAGE

RESTORED

No Noise

Noise



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Unconventional Imaging: Active Pupil-Plane Imaging

- **Problem:**
  - Need fine resolution to identify targets
  - For fine resolution, need short wavelength and large aperture
  - Large apertures are heavy and expensive
  - Also, atmospherics and imperfect optics blur images
- **Solution:** Laser illumination
  - Ensures adequate light level; Day/night operation
  - Enables unconventional coherent imaging modalities
  - Pupil-plane sensing — Minimum depth for light weight, low cost
  - Sparse, distributed detector array
  - Detectors can be conformal to platform
  - Multiple wavelengths --> 3-D
  - Phase retrieval & array phasing algorithms to correct phase error
    - Fourier-domain intensity
    - Image-domain support constraint

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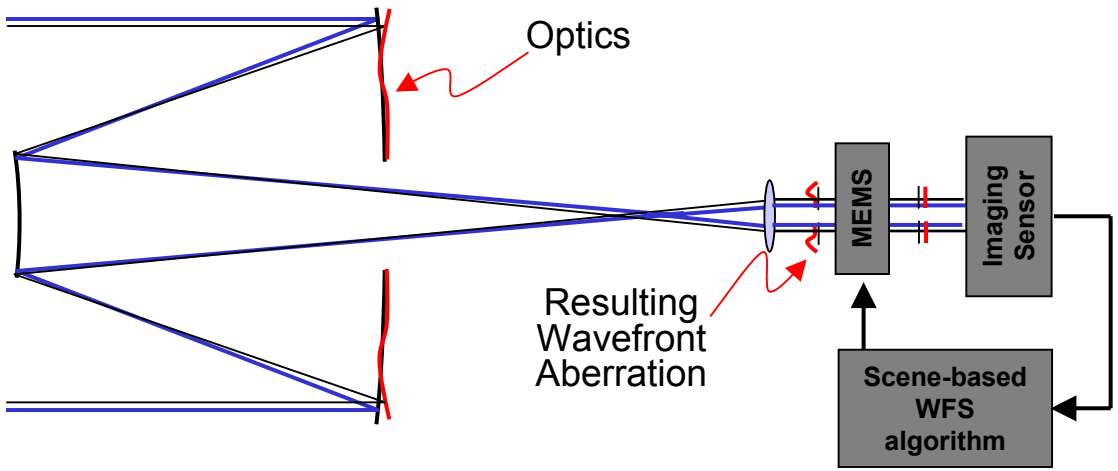
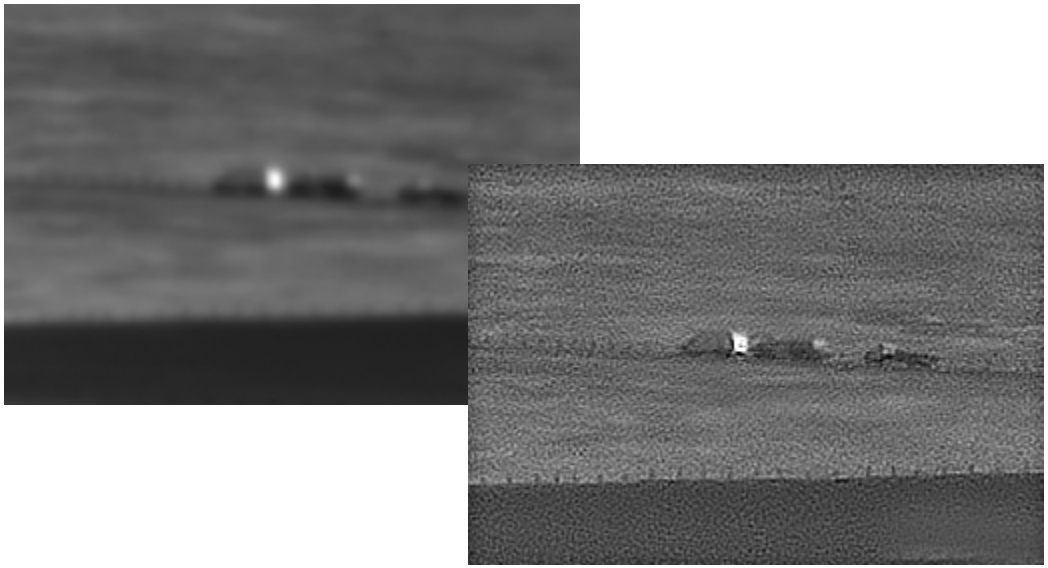
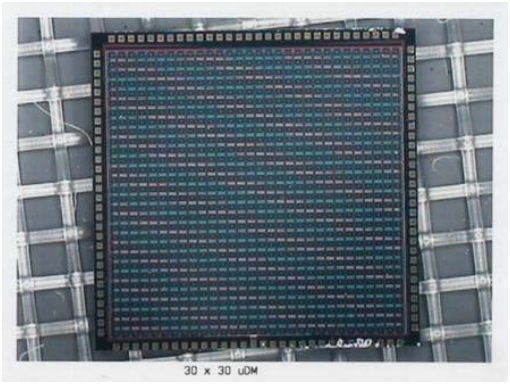
Adaptive optics for horizontal path imaging







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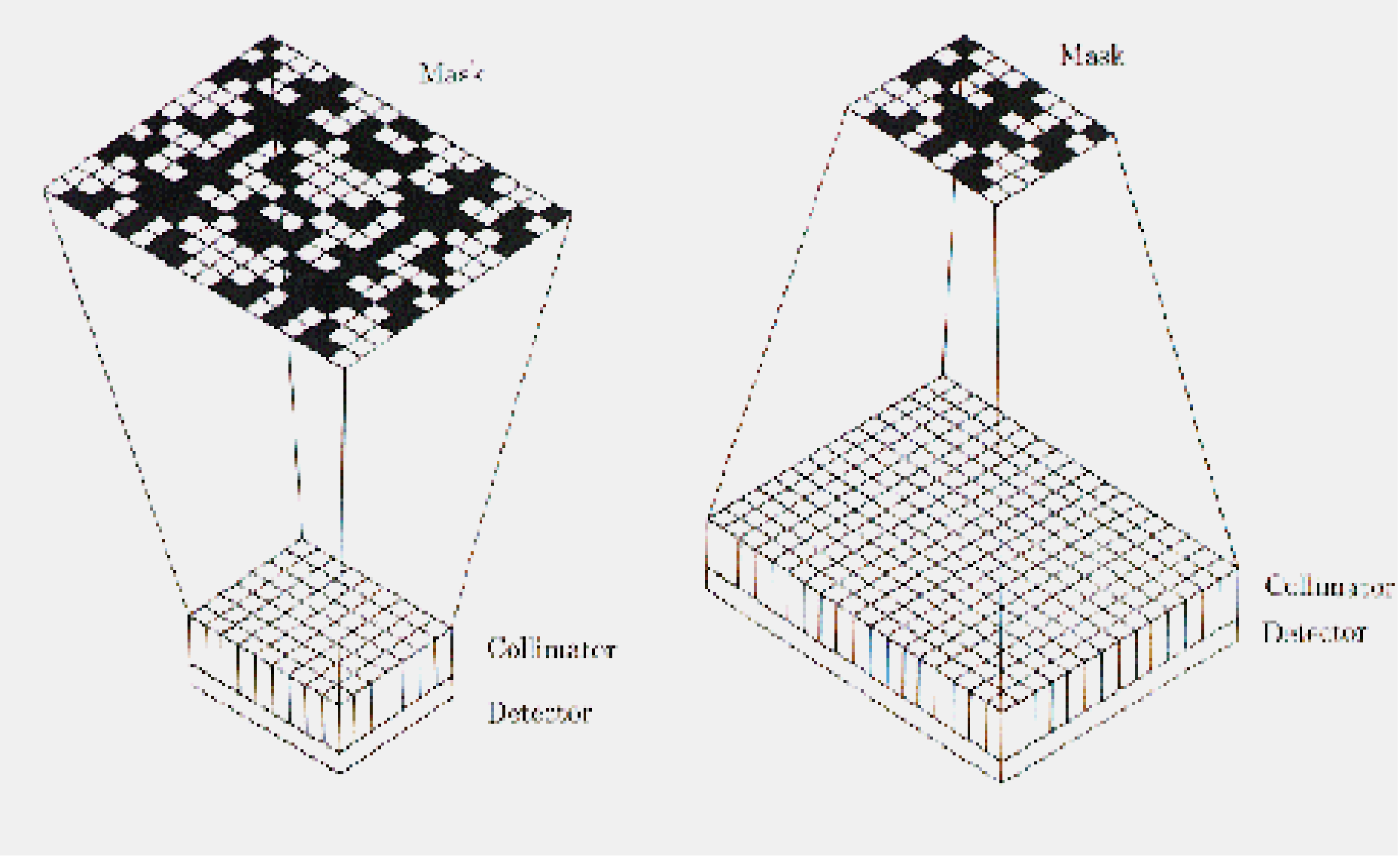

Encoded aperture pinhole camera .

A random collection of pinholes in the screen encodes, locations in the scene.

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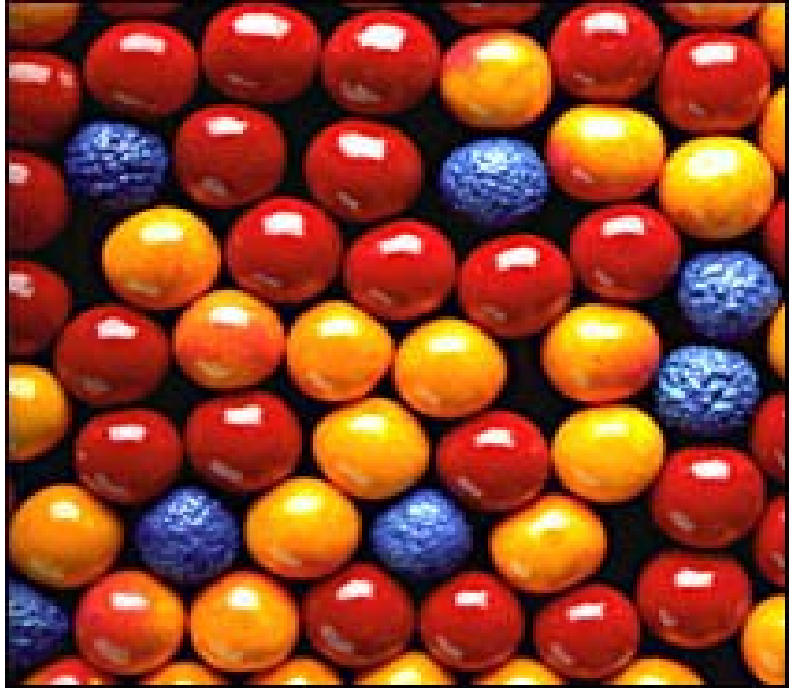

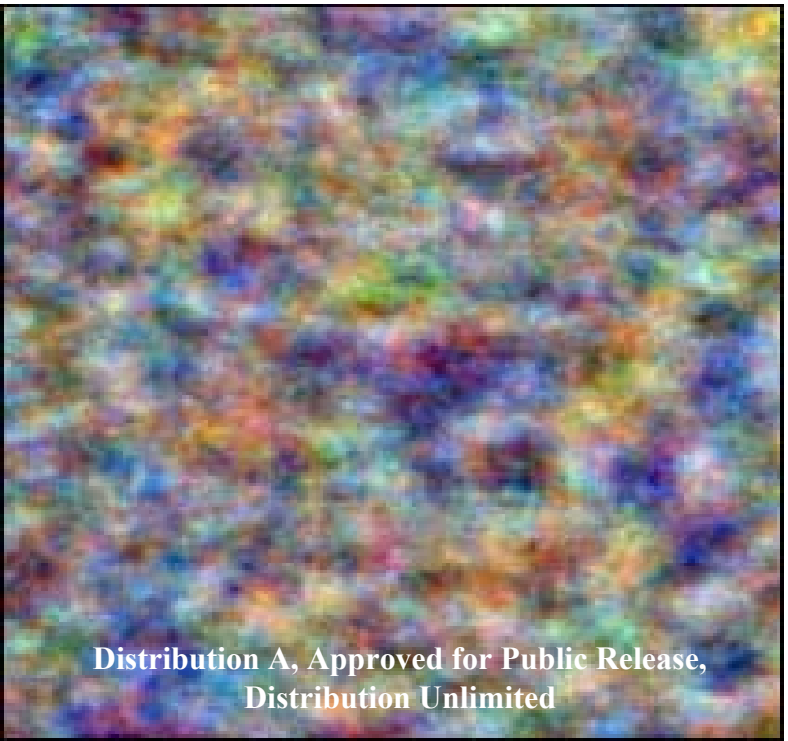

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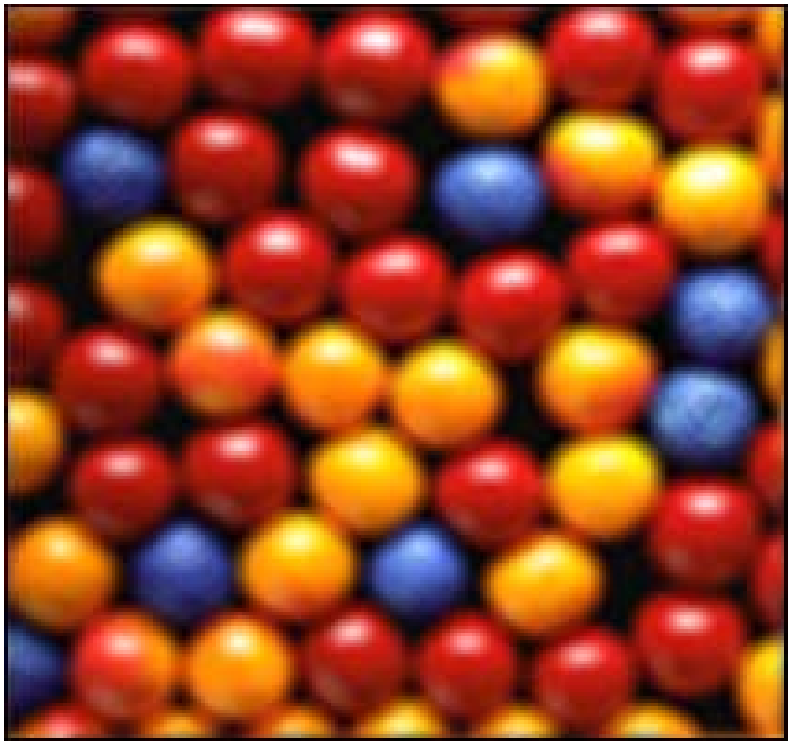

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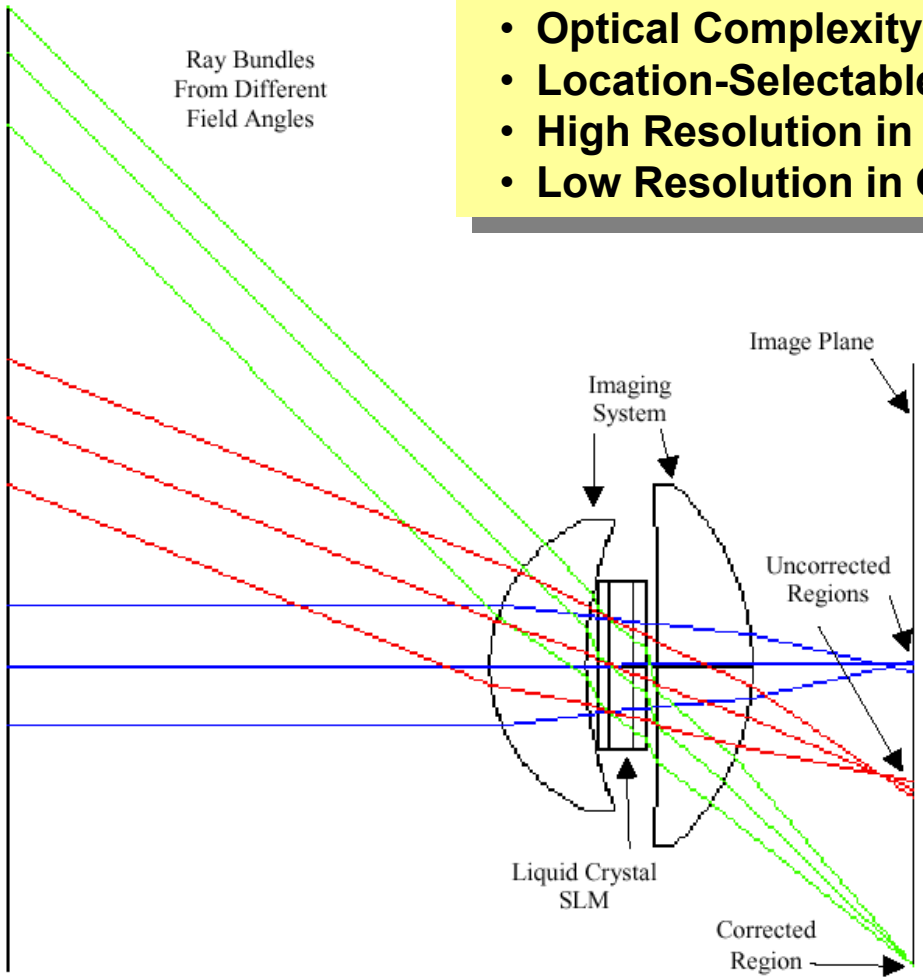
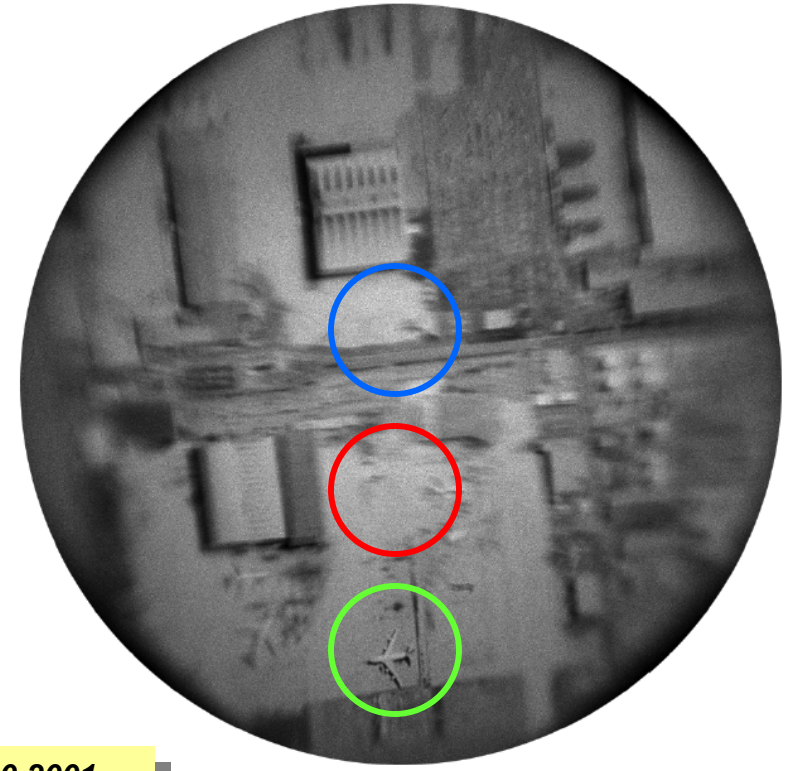
FOVEATED IMAGING SYSTEM

- Optical Complexity, Weight, and Cost are Minimized
- Location-Selectable Narrow Field-of-View (FOV)
- High Resolution in a Narrow FOV preserves max resolution
- Low Resolution in Other Areas Reduces Bandwidth

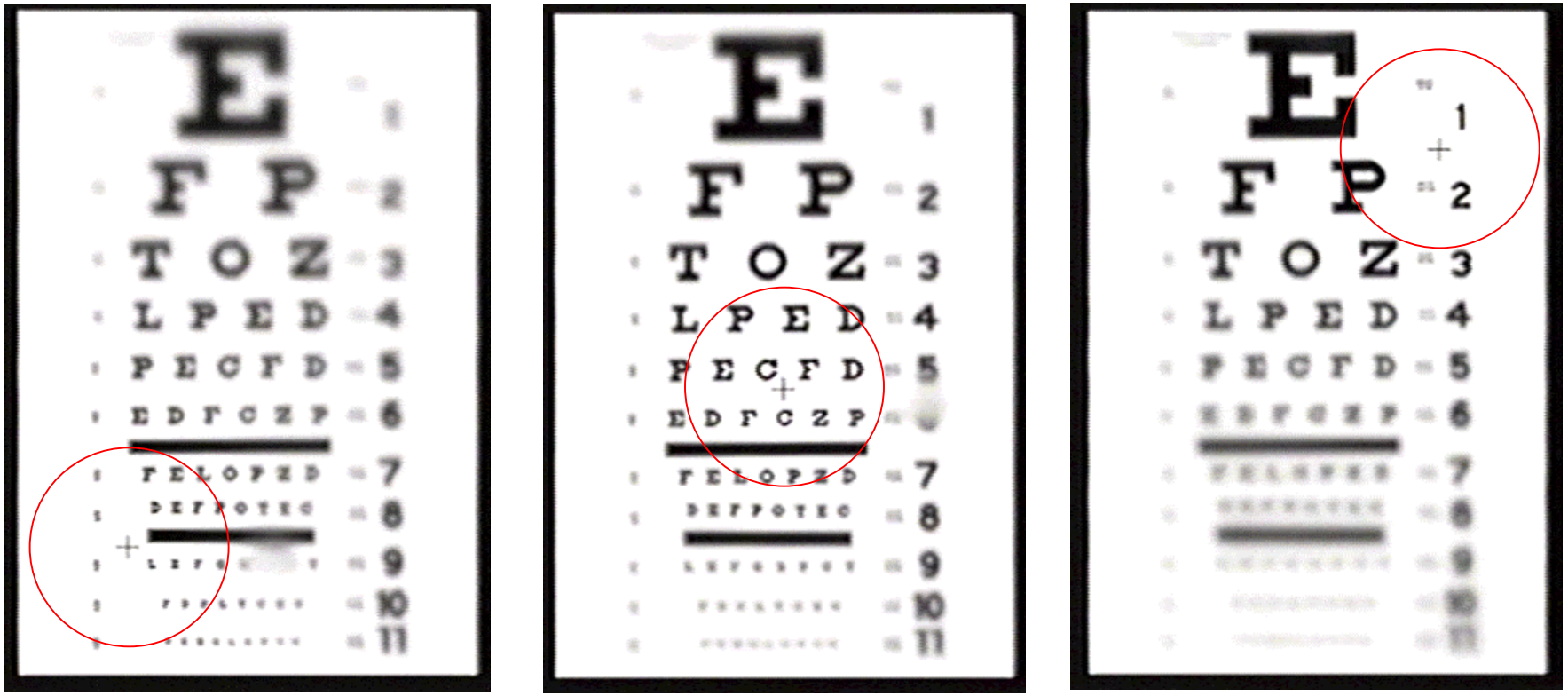




T. Martinez et. al., Optics Express, vol.8, no. 10, p. 555, Apr. 30 2001.

D. Wick et. al., Optics Express, vol. 10, no.1, p. 60, January 2, 2002.

FOVEATED IMAGES: VARIABLE SPATIAL RESOLUTION DEPENDENT ON GAZE POINT



Images obtained using software by J.S. Perry and W.S. Geisler, Univ. Texas at Austin, Center for Perceptual Systems

- Compression achieved above is nominally 4:1
- Matching foveated optic concept is highly synergistic with this type of compression

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